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[Document Name] Specification

[Title of the Invention] Method for Manufacturing Universal Joint Yoke, Forging Die and Preform

[Detailed Description of the Invention]

[0001]

[Technical Field to Which the Invention Pertains]

The present invention relates to a method for manufacturing a universal joint yoke having a thin-walled cup portion and, more particularly, to a forging die for use in the method and to a forged preform.

[0002]

[Background Art]

An example of a component having a thin-walled cup portion is a universal joint yoke for use in a propeller shaft (i.e., drive shaft) of a power train system. FIG. 12 schematically shows a propeller shaft. A propeller shaft connects the outlet of a transmission (111) and a final drive (119) in a power transmission system and uses universal joints at connections of shafts thereof. The universal joints each include a yoke (112a, 112b, or 112c), and a cross member (113a, 113b, or 113c) and are adapted to transmit rotation to shafts (114a and 114b) connected thereto.

[0003]

Universal joint yokes have been manufactured from an extruded aluminum alloy by means of cold forging. FIG. 13 shows an example of a die configuration for use in a conventional cold forging process. FIG. 16 exemplifies an

as-forged article with flash that is obtained by a conventional flash-emerging forging process, and an article that is obtained by trimming the flash.

[0004]

In FIG. 13, an upper die assumes a shape corresponding to a cup portion of a universal joint yoke to be connected to a shaft, and a lower die assumes a shape corresponding to a pin boss portion to be coupled to a cross member. The upper die drops toward the lower die to press an aluminum workpiece therebetween, whereby the shapes of the upper and lower dies are transferred to the workpiece by means of a space that is defined by the upper and lower dies. The aluminum workpiece placed in the lower die is lubricated beforehand and is not preheated. FIG. 14 shows the die configuration for use in the conventional cold forging as viewed at the forging completion stage where the upper die is positioned at the bottom dead center of its stroke. A cup portion of the as-forged article, the cup portion being formed on the side toward the upper die, is formed through free-end forging, which does not involve restraint effected by the upper die.

[0005]

As shown in FIG. 16, the as-forged article obtained by the conventional process involves an uneven height of an excess metal end, for the following reason. Since a cup portion 41 is formed through free-end forging, workpiece material undergoes plastic flow such that much more workpiece material flows toward a pin boss portion 43, so that

workpiece material that flows toward the cup portion 41, which is located axially opposite the pin boss portion 43, is diminished. As a result, quantity of cutting increases, resulting in a drop in yield in terms of material utilization.

[0006]

As shown in FIG. 14, in the conventional forging process, forging starts upon the upper die contacting the workpiece, and an outer circumferential portion of the upper die and an inner circumferential portion of the lower die do not come into contact during the course of forging. The cavity of the lower die is irregularly shaped; i.e., the cavity consists of a pin-boss-forming cavity and a non-pin-boss-forming cavity. This irregular shape of the lower die cavity causes deflection of the upper die during the course of forging. As a result, concentricity becomes about 1 mm between the inner cylindrical wall of a cup portion, which is formed by means of the upper die, and the outer cylindrical wall of the cup portion, which is formed by means of the lower die. Therefore, in the subsequent machining step, the wall thickness of the cup portion is finished uneven. In some cases, the resultant yoke may exhibit insufficient coupling strength in coupling to a shaft.

[0007]

In the conventional forging process, since the occurrence of underfill on a cup portion is unavoidable, a large wall thickness is imparted to the cup portion. Also, in order to obtain a cutting allowance, excess metal is

intentionally added even though the height of an excess metal end becomes uneven. Therefore, poor yield in terms of material utilization results. Also, a height variation of a cup end of an as-forged article is not less than 25 mm, which is in excess of a preferred value of 10 mm.

[0008]

In order to reduce a cutting allowance through attainment of a uniform height of a cup portion, a closed forging process has been devised. However, in some cases, the closed forging process has involved the following problem. Since the volume of a pin boss portion accounts for a great portion of the entire yoke volume, in the course of plastic flow of workpiece material toward a pin-boss-forming cavity, plastic flow of workpiece material is not initiated toward a portion of a cup-forming cavity that is located axially opposite the pin-boss-forming cavity. Therefore, in some cases, there has arisen a problem of underfill in a corresponding region of a cup portion, which is a coupling portion to a shaft. Also, since plastic flow of workpiece material to a portion of the cup-forming cavity that does not have a counter pin-boss-forming cavity occurs in a preferred manner, filling of the portion of the cup-forming cavity is completed at an early stage. Thus, a die load increases, thereby shortening the life of a portion of the die that corresponds to the portion of the cup-forming cavity of early completion of filling. Therefore, the conventional closed forging process is not practical.

[0009]

In order to solve the above-mentioned problem, multi-stage forging must be employed. Specifically, first a pin boss is formed, and then a cup is formed. FIG. 15 shows a die for use in a conventional multi-stage forging process that involves a first stage and a second stage. This process requires dies for use at individual stages and involves a plurality of forging stages, resulting in low productivity and high cost.

[0010]

[Problems to be Solved by the Invention]

Such multi-stage forging requires a plurality of dies and thus involves high die cost. Further, since a plurality of stages are involved, productivity drops. Therefore, multi-stage forging is not practical. Also, as mentioned previously, single-stage forging involves a heavy forging load and thus requires a forging press of a large forging capacity. Further, an increase in die load shortens the life of a die. Thus, demand exists for a single-stage forging process with enhanced productivity.

[0011]

According to the conventional multi-stage forging process, a pin boss portion of a yoke is roughly formed at the first stage. At the subsequent second stage, by use of a finish forging die, the pin boss portion is formed into its final shape, and a cup portion of the yoke is formed axially opposite the pin boss portion. The two pairs of dies are

mounted on the same press or on different presses. In the case of sharing the same press, after the first stage is completed, dies must be changed for the second stage. In either case, setup work and a plurality of forging stages are involved.

[0012]

According to another conceivable manufacturing method, a pin boss portion of a yoke and a cup portion of the yoke, which extend in opposite directions, are formed through single-stage forging. In this case, after formation of the pin boss portion and a region of the cup portion that is located axially opposite a portion of the yoke where no pin boss portion is present, a partially filled portion of a cup-forming cavity, the portion being located axially opposite a pin-boss-forming cavity, must be filled. This filling operation requires a heavy forming load; i.e., a large-sized press. Imposition of a heavy forming load on a die shortens the life of the die and impairs productivity, resulting in an increase in production cost.

[0013]

Japanese Patent Application Laid-Open (*kokai*) No. 2000-263178 discloses a method for forming a cup-shaped article of brass of uniform height. According to this method, first a workpiece is formed into a cup shape, and subsequently a separately driven ram presses the cup-shaped workpiece from above to form an undercut on the workpiece. The method disclosed in the publication uses a workpiece of brass.

Since brass is readily susceptible to plastic flow, a workpiece of brass can be formed under the disclosed conditions. However, because of high resistance to deformation at high temperature, an aluminum alloy is less susceptible to plastic flow as compared with brass and thus cannot be formed under the disclosed conditions.

[0014]

The present invention has been achieved in view of the foregoing, and an object of the invention is to provide a method for manufacturing a universal joint yoke which exhibits good yield in terms of material utilization through obtainment of a universal joint yoke preform whose shape is close to that of a finished product, whose excess metal to be trimmed is diminished, and whose cup portion is of uniform height.

[0015]

[Means for Solving the Problem]

The inventors of the present invention have carried out extensive studies on the relationship between forgeability and product shape, and they have accomplished the present invention on the basis of their findings.

1) In order to achieve the aforementioned object, a first invention provides a method for manufacturing a universal joint yoke, characterized by comprising a forging step for forming a universal joint yoke preform from a workpiece placed in a die comprising an upper die and a lower die, which define a closed space. The forging step is performed

such that, while a back pressure not lower than 0.5 kg/mm^2 is applied to an end of a prospective universal joint yoke cup portion of the workpiece via a ring knock, material of the workpiece is allowed to flow into a pin-boss-forming cavity adapted to form a pin boss portion extending opposite the prospective cup portion, until a filling rate not lower than 75% is reached, and then the ring knock is moved in a direction opposite a regular forming direction of the upper or lower die in which the ring knock is disposed, so as to initiate flow of workpiece material toward the prospective cup portion.

2) In order to achieve the aforementioned object, a second invention provides the manufacturing method as described in 1), wherein the back pressure increases as the ring knock moves in the opposite direction, and a final back pressure is 1.2-2.2 times an initial back pressure.

3) In order to achieve the aforementioned object, a third invention provides the manufacturing method as described in 1) or 2), wherein the back pressure is generated by means of a gas cushion.

4) In order to achieve the aforementioned object, a fourth invention provides the manufacturing method as described in any one of 1) to 3), wherein a back pressure of 1.5-25 kg/mm^2 is initially applied, and then, while the back pressure is held at a value of 0.5-20 kg/mm^2 that is lower than the initially applied value, workpiece material is allowed to flow into the pin-boss-forming cavity until a filling rate

not lower than 90% is reached, followed by movement of the ring knock.

5) In order to achieve the aforementioned object, a fifth invention provides the manufacturing method as described in any one of 1) to 4), wherein the back pressure is generated by means of a hydraulic cushion.

6) In order to achieve the aforementioned object, a sixth invention provides the manufacturing method as described in any one of 1) to 5), wherein the workpiece is of an aluminum alloy selected from among A6061, A6082, A2014, A2017, A4032, and A7075.

7) In order to achieve the aforementioned object, a seventh invention provides the manufacturing method as described in any one of 1) to 6), wherein the workpiece is formed by the steps of cutting a round bar of an aluminum alloy into pieces each having a predetermined length and upsetting each of the pieces, and the method further comprises the steps of heat-treating an as-forged article and machining the heat-treated article.

8) In order to achieve the aforementioned object, an eighth invention provides the manufacturing method as described in 8), wherein the machining step to be performed after the forging step does not involve a step of trimming a parting-line flash of an as-forged article.

9) In order to achieve the aforementioned object, a ninth invention provides a forging die for use in forging a universal joint yoke preform, comprising an upper die and a

lower die, which define a closed space, a ring knock, a knockout pin, a die holder, back pressure generation means for generating a back pressure not lower than 0.5 kg/mm^2 to be applied to the ring knock, and a pressure-bearing plate on which the upper or lower die and the back pressure generation means are disposed.

10) In order to achieve the aforementioned object, a tenth invention provides the forging die as described in 9), wherein the back pressure generation means is a gas cushion and/or a hydraulic cushion.

11) In order to achieve the aforementioned object, an eleventh invention provides a universal joint yoke preform manufactured by the method as described in any one of claims 1 to 8, characterized in that a height variation of the cup portion is not greater than 8 mm.

12) In order to achieve the aforementioned object, a twelfth invention provides a universal joint yoke, characterized in that a parting-line portion does not bear a trimming mark, and the ratio of a crystal grain length as measured at (B) to a crystal grain length as measured at (A); i.e., (B)/(A), is 0.5-1.5, wherein (A) is an end region of a cup portion which is located axially opposite a portion of the yoke where no pin boss portion is present, and (B) is an end region of the cup portion which is located axially opposite a pin boss portion.

Herein, 1 kg/mm^2 is equal to 9.8 MPa (conversion factor).

[0016]

[Modes for Carrying Out the Invention]

An embodiment of the present invention will next be described.

[0017]

FIG. 5 shows an example of a universal joint yoke (hereinafter may be referred to as a "yoke") preform. The preform is composed of at least a coupling portion (cup portion) (41) to be coupled to a shaft, a pin boss portion (43), and a plate portion (42). These portions are machined to their respective final shapes as needed.

[0018]

The cup portion is formed such that the difference between the maximum height and the minimum height; i.e., height variation, is not greater than 8 mm. Since height variation is sufficiently smaller than a preferred value of 10 mm, a cutting step for adjusting the cup height is not required after a forging step. In the case where an end of the cup portion must be machined for later coupling to a shaft; specifically, a shoulder for butting against a shaft end must be formed by means of machining, and the bore diameter of the cup portion must be finished according to a shaft diameter, cutting allowances are determined in view of height variation of the cup portion. In the case of the preform of the present invention, since the height variation is not greater than 8 mm, the cutting allowances can be reduced. Also, time required for machining the cup portion can be shortened, thereby enhancing productivity.

[0019]

The preform of the present invention is characterized in that no flash is formed at a parting-line portion (a portion corresponding to a portion of a conventional preform denoted by reference numeral 44 in FIG. 16). Since no flash is formed; i.e., no plastic flow to form the flash arises, the mechanical strength of the portion is enhanced. Also, a drop in yield in terms of material utilization, which would otherwise result, is not involved.

[0020]

FIG. 6 shows an example of a universal joint yoke of the present invention. The universal joint is obtained by means of machining a preform. The universal joint yoke of the present invention is composed of at least a coupling portion (cup portion) (91) to be coupled to a shaft, a pin boss portion (43), pin holes (94a and 94b), and a plate portion (42). The universal joint yoke of the present invention is characterized in that a parting-line portion does not bear a flash trimming mark. Since no flash is formed; i.e., no plastic flow to form the flash arises, the mechanical strength of the portion is enhanced. Also, a drop in yield in terms of material utilization, which would otherwise result, is not involved. In observation of traces of plastic flow on the sections, taken along the longitudinal direction (the direction extending from an end region of the cup portion to a root region of the cup portion), of end regions of the cup portion of the universal joint yoke of the

present invention, the ratio of a crystal grain length as measured at (B) to a crystal grain length as measured at (A) is 0.5-1.5, wherein (A) is an end region of the cup portion which is located axially opposite a portion of the yoke where no pin boss portion is present, and (B) is an end region of the cup portion which is located axially opposite a pin boss portion. This feature indicates that mechanical strength is uniform, and is favorable in terms of machining and practical use of the product.

[0021]

A configuration example of a power train system in which universal joint yokes of the present invention are incorporated will be described specifically with reference to FIG. 12. Reference numeral 112 denotes a yoke, which has pin holes (94a and 94b) formed in a pin boss portion (43). The pin holes (94a and 94b) are formed by means of machining and serve as coupling portions to a cross member. Referring to FIG. 12, in which a portion of the power train system is omitted, yokes are used in pairs such that one yoke is coupled to its counterpart via a cross member (113), which is fitted into the pin holes formed in the paired yokes. The inside diameter of a cup portion (91) is finished by means of machining according to the diameter of a shaft (114). The cup portion (91) is joined to the shaft (114) by means of, for example, arc welding such as MIG welding (Metal Inert Gas arc welding) or TIG welding (Tungsten Inert Gas arc welding), friction welding, or friction stir welding.

[0022]

A configuration example of a forging apparatus for use in the present invention will be described with reference to FIG. 8.

The forging apparatus includes a forging press (221), an upper die (103), and a lower die (105). A pneumatic cylinder (231), which serves as a back pressure generation means, is incorporated in an upper portion of the upper die. A knockout pin for ejecting an as-forged article is disposed in the lower die. Reference numeral 108 denotes a spray moving unit, reference numeral 109 denotes a spray rotating unit, and reference numeral 110 denotes a spray shaft. A spray nozzle (104) is supported by the spray rotating unit and the spray moving unit via the spray shaft and adapted to spray lubricant on the die.

[0023]

The forging die of the present invention will be described in detail.

FIG. 4 is a schematic sectional view showing an example of an upper die for use in the manufacturing method of the present invention. The upper die includes a center punch (66) for forming the interior shape of a cup portion, a knock ring (67) for forming a cup portion end through application of back pressure, a gas cushion (74) serving as means for generating the back pressure, a pressure-bearing plate (70), which supports the ring knock (67) and the gas cushion (74), and a punch holder (69), which supports the center punch (66),

etc. and is fixedly attached to an upper bolster (1). The gas cushion (74) can be composed of, for example, pneumatic cylinder pressure transmission spindles (68), pneumatic cylinders (71), and pneumatic cylinder gas confinement sections (72). The ring knock is subjected to the back pressure which is transmitted from the pneumatic cylinders via the pneumatic cylinder pressure transmission spindles. Therefore, upon subjection to a force greater than a pneumatic cylinder pressure, the ring knock can move rearward in relation to the upper die.

[0024]

Preferably, before forming starts, the back pressure generated by the pneumatic cylinders causes the ring knock to be positioned such that the end face of the ring knock is aligned with or projects beyond the end face of the center punch, which is adapted to form the interior shape of the cup portion. If the ring knock end is retracted from the center punch end face, a back pressure effect is not yielded as expected. Through the end face of the ring knock being aligned with or projecting beyond the end face of the center punch, the center punch is fitted into the lower die, thereby enhancing positioning accuracy.

[0025]

The inner pressure or the number of the pneumatic cylinders is adjusted such that the pneumatic cylinders impose a back pressure of 0.5-20 kg/mm^2 on the ring knock. The inner pressure or the number of the pneumatic cylinders

is adjusted such that, after workpiece material occupies a pin-boss-forming cavity by a filling rate not less than 75%, the ring knock is moved in the direction opposite the regular forming direction of the upper or lower die in which the ring knock is disposed.

[0026]

The gas cushion, which serves as a back pressure generation means, is incorporated in the upper die. According to the die configuration of the present invention, the gas cushion is disposed such that one end thereof is fixed on the upper bolster, and adapted to transmit stress to the ring knock via the pressure transmission spindles. In addition to the pneumatic cylinder pressure transmission spindle, examples of a pressure transmission spindle include a knockout pin and a block.

[0027]

No particular limitation is imposed on back pressure generation means so long as the means can generate pressure over the entire stroke of die movement during the course of forming. In addition to the gas cushion, examples of back pressure generation means include a hydraulic cushion, a spring, a coil spring, and rubber.

[0028]

A gas cushion, when used as back pressure generation means, can provide sufficient back pressure without feed of pressure from the outside, and thus can be incorporated into a die. Thus, use of the gas cushion allows elimination of a

pressure generation unit, which would otherwise be attached to a press, and does not require a die set equipped with dedicated pressure transmission piping. Therefore, the gas cushion can be readily attached to a general-purpose press or die set. When a spring, a coil spring, or rubber is used as back pressure generation means, the similar effect can be yielded.

[0029]

A gas cushion, when used as a back pressure generation unit, exhibits excellent durability to repeated expansions and contractions and provides a wide range of sizes and stroke lengths to allow adequate selection according to applications.

[0030]

Preferably, a back pressure generation mechanism is a spring, a coil spring, or rubber. Since component parts of many types and sizes are available for such a back pressure generation mechanism, the range of choice of a die structure is expanded, and the cost of the back pressure generation mechanism drops.

[0031]

Examples of material for the ring knock include die steel and powder high-speed steel. Examples of materials for die component members include die steel, powder high-speed steel, and cemented carbide. Preferably, in order to ensure the sliding operation between the ring knock and the upper die and that between the ring knock and the lower die, die

surfaces on which the ring knock slides are nitrided or coated with molybdenum. Such die surfaces are, for example, an outer surface of the upper die that is adapted to form the inner wall of the cup portion, and an inner surface of the lower die that is adapted to form the outer wall of the cup portion. The clearance between the ring knock and the upper die and that between the ring knock and the lower die are preferably about 0.05-0.3 mm. When the clearance is not greater than 0.05 mm, smooth sliding cannot be attained, and application of lubricant becomes difficult. A clearance not less than 0.3 mm is favorable in terms of sliding and application of lubricant, but raises a problem of flash formed in the clearance.

[0032]

FIGS. 1, 2, and 3 schematically show forging operations and a die for use in a manufacturing method according to an embodiment of the present invention. The forging process will next be described sequentially.

[0033]

As shown in FIG. 2, a forging workpiece is placed in the lower die. Then, as shown in FIG. 1, the upper die drops. The ring knock, which partially constitutes the upper die, is first fitted into the lower die, thereby ensuring that the upper die and the lower die are coaxially aligned.

[0034]

As the upper die drops further, the workpiece is held within a closed space that is defined by the upper and lower

dies. At the initial stage of forming, material of the workpiece undergoes plastic flow mainly toward a pin-boss-forming cavity. The ring knock of the upper die is subjected to the back pressure imposed by the pneumatic cylinder and thus restricts plastic flow of the workpiece material toward a cup-forming cavity. At this time, a back pressure not less than 0.5 kg/mm^2 is imposed on an end of a prospective cup portion of a workpiece via the ring knock. After the workpiece material occupies a pin-boss-forming cavity by a filling rate not less than 75%, the ring knock moves rearward. As the contraction of a pneumatic cylinder proceeds, the pressure of the pneumatic cylinder increases. Also, as the upper die approaches the bottom dead center of the press, the forming load (the pressure imposed in the lowering direction of the upper die) increases. Therefore, while appropriately maintaining the balance between the pneumatic cylinder pressure and the forming load, and imposing a load on the workpiece material, the ring knock retreats in the direction opposite the moving direction of the upper die. FIG. 9 shows the relationship between a ring knock stroke and the back pressure.

[0035]

In the case where a pneumatic cylinder is used to generate back pressure, the initial pressure as measured when the ring knock comes into contact with a workpiece and begins to impose a load on the workpiece can be set by means of the inner pressure of the pneumatic cylinder. Subsequently, the

contraction of the cylinder causes an increase in the inner pressure, and thus the load pressure increases toward the stroke end of the cylinder. The increasing load pressure functions to adjust the cup portion end to uniform height.

[0036]

In the case where a spring is used to generate back pressure, the back pressure assumes the minimum value when the ring knock comes into contact with a workpiece and begins to impose a load on the workpiece, since the spring is in an expanded state. Subsequently, the contraction of the spring causes an increase in the elastic force of the spring, and thus load pressure increases toward the stroke end of the spring. The increasing load pressure functions to adjust the cup portion end to uniform height.

[0037]

In the present embodiment, the timing of moving the ring knock after workpiece material occupies a pin-boss-forming cavity by a filling rate not less than 75% is adjusted beforehand by means of back pressure. However, the timing may be adjusted by means of press stroke position control or timer control.

[0038]

When workpiece material occupies the pin-boss-forming cavity by a filling rate not less than 75%, an end portion of a prospective pin boss portion comes into contact with the die surface, and the corner radius R (the radius of a corner curvature) of the prospective pin boss portion is 8-15 mm.

When the die cavity is completely filled with workpiece material so that the die shape is transferred to the workpiece, the corner radius R assumes a value of, for example, 5 mm. The filling rate is defined as (volume of workpiece material occupying pin-boss-forming cavity/volume of pin-boss-forming cavity of die) x 100(%).

[0039]

When forming proceeds to such a state that the pin-boss-forming cavity is substantially filled with workpiece material, the upper die still continues lowering, and forming pressure becomes greater than the pressure that is imposed on the ring knock of the upper die by the pneumatic cylinder. Therefore, the ring knock retreats to the upper end of its stroke, and thus, as shown in FIG. 3, the cup-forming cavity is also filled with the workpiece material. In the case where back pressure is generated by a gas cushion, as the ring knock retreats, the back pressure transmitted from a pneumatic cylinder increases up to 120%-220% of an initial back pressure. As a result of this increase of back pressure, while the cup-forming cavity is being filled with the workpiece material, an unfilled portion of the pin-boss-forming cavity is filled with the workpiece material, whereby forming is completed. This back pressure increase accelerates the forming of the cup portion and the filling of an unfilled portion of the pin-boss-forming cavity. Since high back pressure is imposed on a cut end at the time of completion of forming, a height variation of the cup end

reduces.

[0040]

Preferably, the stroke end position of the cylinder of the back pressure generation unit is set slightly above the bottom dead center of the press, whereby potential damage to the cylinder can be avoided.

[0041]

Since the manufacturing method of the present invention uses the above-described die, a back pressure not lower than 0.5 kg/mm^2 (a back pressure of 1-5 kg/mm^2 is preferred for hot forging; and a back pressure of 10-15 kg/mm^2 is preferred for cold forging) is imposed on a workpiece via the ring knock.

[0042]

A back pressure of 0.5-20 kg/mm^2 is preferred in the following reason. When the back pressure imposed on an end of a prospective cup portion is less than 0.5 kg/mm^2, the flow of workpiece material becomes nonuniform, and thus the amount of material flow to a cup-forming cavity varies according to position. As a result, the height of an end of an as-formed cup portion becomes nonuniform. FIG. 11 shows the relationship between height variation and the lowest back pressure. When the back pressure exceeds 20 kg/mm^2, the flow of workpiece material to the cup-forming cavity is excessively restricted. As a result, the workpiece material fails to reach a target height in the cup-forming cavity, and a reaction force may cause an as-formed cup portion to be

deformed (buckled).

[0043]

When the die cavity is completely filled with workpiece material to thereby complete forming, the upper die rises, and, at the same time, the inner pressure of the pneumatic cylinder disposed in the upper die causes the ring knock to press down an upper end of a cup portion of an as-forged article, thereby removing the article from the upper die. The ring knock having a back pressure generation mechanism also has an as-forged article ejection function. The ring knock can prevent adhesion of an as-forged article to a punch, which would otherwise tend to arise when the punch is used to form the cup portion.

[0044]

After the upper die has risen, a knockout pin rises from underneath the lower die to push up the as-forged article to the top surface of the lower die, whereby the as-forged article is ejected from the die.

[0045]

Next will be described an embodiment in which the initial back pressure is increased so as to increase the filling rate of the pin-boss-forming cavity, and subsequent forming is carried out while the back pressure is held lower than the initial pressure. This embodiment allows the reduction of forming load during the course of forming the cup portion, thereby enhancing the life of the die.

[0046]

The present embodiment employs, for example, a hydraulic cushion as back pressure generation means. The hydraulic cushion may be configured in a manner similar to that of the previously described pneumatic cylinder; i.e., oil is used in place of air.

[0047]

Preferably, the initial back pressure is 1.5-25 kg/mm^2, and the back pressure during the course of subsequent forming assumes a value of 0.5-20 kg/mm^2 that is lower than the initial value.

[0048]

In the case where the back pressure is hydraulically generated, as shown in FIG. 10, the initial back pressure as measured when the ring knock comes into contact with a workpiece and begins to impose load on the workpiece (when a hydraulic cylinder begins to contract) is high, and the subsequent back pressure can be maintained at a constant value not lower than 0.5 kg/mm^2 over a period of time ranging from the start of contraction of the hydraulic cylinder to the end of forming, since the back pressure is not influenced by the stroke of the hydraulic cylinder. Therefore, the present embodiment exhibits enhanced forming performance. For example, the hydraulic cylinder operation can be set such that the ring knock does not start retreating until the pin-boss-forming cavity is completely filled (e.g., preferably until a filling rate not less than 90% is reached), thereby avoiding the occurrence of underfill on the pin boss portion.

Since the ring knock retreats while the back pressure is maintained at a constant level, the cup portion height becomes uniform.

[0049]

Preferably, hydraulic control is employed so as to change pressure setting according to product types. For example, the pressure of an external hydraulic unit is controlled by means of a forming slide signal. Alternatively, the hydraulic cylinder pressure may be regulated simply by means of a pressure reducing valve or the like.

[0050]

Preferably, the back pressure is regulated in the following manner. The initial back pressure is 1.5-25 kg/mm^2, and the subsequent back pressure assumes a value of 0.5-20 kg/mm^2 that is lower than the initial value. For example, the back pressure is 5 kg/mm^2 at a press angle range of 90° to 120°, the back pressure is decreased to 3 kg/mm^2 over a press angle range of 120° to 160°, and the back pressure is maintained at 3 kg/mm^2 over a press angle range of 160° to 180° so as to prevent potential buckling at the time of knockout. In order to change the back pressure from 5 kg/mm^2 to 3 kg/mm^2, two parallel hydraulic lines of 3 kg/mm^2 and 2 kg/mm^2 are operated such that a 120° signal causes the 2 kg/mm^2 line to be drained.

[0051]

The pressure control may be combined with the aforementioned back pressure generation means so as to change

pressure patterns, thereby providing load patterns to choose from according to product types.

[0052]

A hydraulic cushion serving as a back pressure generation unit can generate an initial pressure higher than the pressure of charged oil by virtue of the flow resistance of oil. The hydraulic cushion exhibits excellent durability to repeated expansions and contractions and provides a wide range of sizes and cushion stroke lengths to allow adequate selection according to applications. The hydraulic cushion is compact and thus can be readily disposed within a die.

[0053]

The above-described die has the ring knock incorporated in the upper die. However, the ring knock may be incorporated in the lower die, or the ring knock may be incorporated in each of the upper and lower dies. FIG. 7 shows a die configuration in which the ring knock is incorporated in the lower die.

[0054]

An upper die that has a ring knock incorporated therein for forming a thin-walled cup portion has the following advantage. Since the direction of material flow in a cup-forming cavity is opposite the pressing direction of the upper die, the frictional resistance between workpiece material and the die decreases, and thus the forming load drops.

[0055]

The die of the present invention is a forging die for use in forging a universal joint yoke preform and includes an upper die and a lower die, which define a closed space, a ring knock, a knockout pin, a die holder, back pressure generation means for generating a back pressure not lower than 0.5 kg/mm^2 to be applied to the ring knock, and a pressure-bearing plate on which the upper or lower die and the back pressure generation means are disposed. Thus, the die of the present invention is applicable to such a case where a conventional large-sized back pressure apparatus cannot be disposed since a forging press is of a short stroke and a narrow spacing between die sets. Since the die of the invention is applicable to a small-sized forging apparatus, the cost of equipment can be reduced.

[0056]

FIG. 17 shows a forging press configuration in which a conventional back pressure apparatus is disposed. The forging press must be equipped with a hydraulic pressure generation unit 224 for moving the upper and lower dies, a press operation monitoring unit 225 for monitoring press operations and generating an electric signal to instruct the hydraulic pressure generation unit 224 to generate hydraulic pressure, back pressure die sets 229a and 229b in which hydraulic cylinders 222a and 222b are disposed respectively, and others. Further, the forging press must have a wide space between the upper and lower bolsters.

[0057]

The die of the present invention is configured such that a compact back pressure generation mechanism is incorporated in the upper die and/or the lower die. Therefore, while a conventional die set is used intact, a conventional die may merely be replaced with the die of the present invention, whereby an as-forged article having a cup portion of uniform height can readily be obtained by means of a mechanism that imposes stress in the direction opposite the regular forming direction.

[0058]

A method for manufacturing a universal joint yoke preform by use of the die of the present invention performs forging such that, while a back pressure not lower than 0.5 kg/mm^2 is applied to an end of a prospective universal joint yoke cup portion of a workpiece via a ring knock, the material of a workpiece is allowed to flow into a pin-boss-forming cavity adapted to form a pin boss portion extending opposite the prospective cup portion, until a filling rate not lower than 75% is reached, and then the ring knock is moved in the direction opposite the regular forming direction of the upper or lower die in which the ring knock is disposed, so as to initiate the flow of workpiece material toward the prospective cup portion.

[0059]

As a result, the flow of the workpiece material toward the prospective cup portion can be sufficiently suppressed such that the workpiece material can flow into the pin-boss-

forming cavity in precedence to a cup-forming cavity until a filling rate not less than 75% is reached. Subsequently, at a point of time when the influence of a material flow toward the pin-boss-forming cavity on a material flow toward the cup-forming cavity diminishes, the flow of the workpiece material toward the cup-forming cavity can be initiated, whereby underfill on an end region of an as-formed cup portion can be suppressed to a small degree. A material flow toward the cup-forming cavity is not excessively suppressed; a cup portion having a uniform target height can be formed; and an as-formed cup portion is free from deformation such as buckling.

[0060]

Next will be described an embodiment of the method of the present invention for manufacturing a universal joint yoke by use of the apparatus of FIG. 2.

The manufacturing method of the present invention includes the steps of placing a workpiece in a die; applying lubricant to the workpiece; preheating the workpiece to a predetermined temperature; applying lubricant to the die; forging the workpiece; and ejecting an as-forged article (forged product: yoke preform) by means of a knockout mechanism.

Preferably, the manufacturing method further includes the preforging steps of cutting a round bar of an aluminum alloy into pieces each having a predetermined length, and upsetting each of the cup pieces to obtain forging

workpieces; and the afterforging steps of heat-treating an as-forged article, and machining the heat-treated article without involvement of trimming.

[0061]

Preferably, a yoke material for use in the manufacturing method of the present invention is an aluminum alloy. In order to meet, for example, the need for reducing the weight of automobiles, demand exists to use an aluminum alloy as material for yokes, since an aluminum alloy exhibits a high specific strength and facilitates the reduction of weight of articles, as compared with iron and brass. In a forging process, the material of a workpiece is moved under pressure over a relatively long distance into a die cavity so as to fill the cavity. When the workpiece is of an aluminum alloy, the forging process encounters difficulty in filling the die cavity with the workpiece material, since, even at high temperature, the aluminum alloy exhibits low ductility/malleability and thus high deformation resistance. Therefore, a conventional single-stage forging process—which is intended to forge brass or a like material and attains a plastic working rate not lower than 70% through utilization of high ductility of such material at high temperature—encounters difficulty, when used to forge an aluminum alloy article, in obtaining underfill-free good quality through sufficient filling of a die cavity with workpiece material. In the present invention, the forging step is performed such that, while a back pressure not lower

than 0.5 kg/mm^2 is applied to an end of a prospective universal joint yoke cup portion of a workpiece via a ring knock, the material of the workpiece is allowed to flow into a pin-boss-forming cavity adapted to form a pin boss portion extending opposite the prospective cup portion, until a filling rate not lower than 75% is reached, and then the ring knock is moved in the direction opposite the regular forming direction of the upper or lower die in which the ring knock is disposed, so as to initiate the flow of workpiece material toward the prospective cup portion. Therefore, underfill-free good quality can be obtained through sufficient filling of a die cavity with the workpiece material.

[0062]

Examples of materials having favorable corrosion resistance and high-temperature strength, and high elasticity include A6061, A6082, A2014, A2218, A4032, and A7075 of JIS. These materials are aluminum alloys having the following composition: Al-0.4% to 0.8% by mass Si-0.15% to 0.40% by mass Cu-0.8% to 1.2% by mass Mg-0.04% to 0.35% by mass Cr. A6061 and A6082 have balanced characteristics; i.e., excellent corrosion resistance and anodic oxidation, and medium strength. A2014 and A2218 have high strength and high elasticity and are thus favorably used as materials for heavy-load yokes, since the strength of the yokes is enhanced. A4032 has excellent wear resistance and high elasticity and is thus favorably used as a material for yokes which must be resistant to wear associated with sliding on a cross member,

since the wear resistance of the yokes is enhanced. A7075 exhibits the highest strength among aluminum alloys of practical use and is thus favorably used as a material for yokes which must have as high strength as that of iron, since the strength of the yokes is enhanced to the required level. Among alloys of practical use, aluminum alloys are light and exhibit excellent toughness. Among these aluminum alloys, A6061—which has medium strength and excellent corrosion resistance—is favorably used as a material for yokes. Favorable materials for yokes which must have high strength are 2000-series aluminum alloys, which are Al-Cu alloys, and 7000-series aluminum alloys, which are Al-Zn alloys—the Al-Cu and Al-Zn alloys having as high strength as that of iron. 4000-series aluminum alloys—which are Al-Si alloys and have excellent wear resistance—are favorably used as materials for those parts (such as cross members) which involve a potential problem of wear associated with contact with other parts.

[0063]

A round bar of an aluminum alloy is formed through extrusion or continuous casting. The thus-obtained round bar of an aluminum alloy is cut into pieces each having a predetermined length. These pieces are upset into forging workpieces.

[0064]

A round aluminum bar having a diameter smaller than the outside diameter of a product is cut into pieces each having

such a length that the volume of the piece is equivalent to that of the product. Each of the cut pieces is upset to assume a diameter that is 0.5-5 mm smaller than the outside diameter of the product. The thus-upset pieces are formed into yokes through forging. In sawing a round bar, the material of the round bar is wasted in the form of cutting chips, which are portions of the round bar which are cut away by a saw and each have a width equivalent to the thickness of the saw. Therefore, use of a round bar of a small diameter is preferred, since high yield in terms of material utilization is attained. Further, the upsetting process enhances the ductility of workpieces. Because of subjection to repeated load, yokes must have good toughness. The enhancement of ductility leads to the enhancement of toughness. A width variation among cutout portions of a bar during the course of sawing less influences a volume variation among cut pieces in cutting a small-diameter bar than in cutting a large-diameter bar. Thus, use of a small-diameter bar leads to a reduction in the degree of overload on a die during the course of forging.

[0065]

As shown in FIG. 2, a forging workpiece is placed in the lower die of the forging apparatus having the aforementioned die. Forging workpieces may be obtained by, for example, cutting a continuously cast bar into pieces each having a predetermined length. The workpieces are lubricated beforehand as needed. Examples of lubrication processes for

workpieces include Bonderite treatment and the application of an aqueous graphite lubricant through immersion in the lubricant. In the case where a workpiece undergoes intensive plastic working at such a high plastic working rate that base aluminum is exposed with a resultant exposure of a fresh surface of a silver metal gloss, Bonderite treatment is preferred in order to prevent lubrication failure. In the case of forming a product having an outside diameter not less than 90 mm, a workpiece may be upset beforehand in order to assume a relevant large diameter.

[0066]

Before being placed in a die, a workpiece is preheated to a temperature of, for example, 370°C-550°C.

[0067]

Lubricant is applied to the die. Lubricant to be used is an aqueous graphite lubricant or an oil-base graphite lubricant. Since lubricant is applied to the die while the ring knock is retracted in the upper die, an oil-base graphite lubricant, which is highly permeable into a clearance, is preferred. Preferably, lubricant is applied to the die in an amount of 1 g to 10 g (concentration: 0.5-25% by mass).

[0068]

Next, the forging process will be described.

First, major forging is performed. The upper die drops, and a workpiece is restrained between the upper and lower dies. The material of the workpiece flows into a pin-boss-

forming cavity engraved in the lower die, whereby a pin boss portion is roughly formed. At this stage, a material flow is mainly directed toward the pin-boss-forming cavity, whereas a material flow is hardly directed toward a prospective cup portion of the workpiece located around the upper die, since a pneumatic cylinder pressure is imposed on the prospective cup portion via the ring knock. At this stage, distal portions of the pin-boss-forming cavity are not filled with the workpiece material.

[0069]

Even after being fitted into a lower die bore, the upper die continues lowering, whereby the workpiece material reaches up to the distal portions of the pin-boss-forming cavity to thereby fill the cavity. At this stage, the forming load becomes greater than the pressure of the pneumatic cylinder disposed in the upper die to thereby cause the rig knock to rise, whereby the workpiece material begins to flow into a cup-forming cavity and then fills the cavity.

[0070]

Since the upper die is fitted into the bore formed in the lower die over the period of time ranging from the start of forming to the completion of forming, the concentricity between the inner cylindrical wall of the cup portion and the outer cylindrical wall of the cup portion is not greater than 0.2 mm, which is the clearance between the upper and lower dies. Since the upper and lower dies are in a closed condition, the exterior surface of an as-forged article does

not require trimming.

[0071]

Forging conditions can be optimized according to product shapes. For example, forging conditions are set as follows: press speed 10-40 spm; back pressure imposed on ring knock 0.5-20 kg/mm^2; and workpiece temperature 200°C or higher (solidus temperature -20°C).

The die is heated beforehand to a temperature of 100°C to 400°C.

[0072]

After forging is completed, an as-forged article is ejected by means of the knockout pin.

[0073]

The as-forged article is preferably heat-treated. The heat treatment is intended to enhance the mechanical strength of a forged preform and performed in the following manner. The as-forged article is allowed to stand at a temperature of 460°C to 560°C for 1-5 hours and is then immediately immersed in a water bath (water temperature 10°C-70°C). Then the article is allowed to stand at a temperature of 150°C to 250°C for 1-10 hours, whereby a forged preform having a predetermined strength can be obtained.

[0074]

The obtained as-forged article is a universal joint yoke preform that is manufactured in the following manner. While a back pressure not lower than 0.5 kg/mm^2 is applied to an end of a prospective yoke cup portion of a workpiece via a

ring knock, the material of the workpiece is allowed to flow into a pin-boss-forming cavity adapted to form a pin boss portion extending opposite the prospective cup portion, until a filling rate not lower than 75% is reached. Then the ring knock is moved in the direction opposite the regular forming direction of the upper or lower die in which the ring knock is disposed, so as to initiate the flow of workpiece material toward the prospective cup portion.

The obtained as-forged article is a universal joint yoke preform characterized in that a height variation of a cup portion thereof is suppressed to not greater than 8 mm through manufacture by use of a mechanism for imposing stress in the direction opposite the regular forming direction.

[0075]

The forged article which has undergone heat treatment undergoes drilling, which is performed by use of a machining center, for drilling pin holes, and machining, which is performed by use of an NC lathe, for forming a shaft coupling portion, whereby the article is finished to a yoke.

[0076]

Since a height variation of a cup portion is not greater than 8 mm, the forged article does not need to undergo machining for correcting the height variation of a cup end thereof. Therefore, there is obtained a universal joint yoke preform that does not need to undergo machining for correcting a height variation of a cup end thereof. The fact that a height variation of a cup portion is not greater

than 8 mm indicates the following: in observation of traces of plastic flow on the sections, taken along the longitudinal direction (the direction extending from an end region of the cup portion to a root region of the cup portion), of end regions of the cup portion of a yoke, the ratio of a crystal grain length as measured at (B) to a crystal grain length as measured at (A); i.e., (B)/(A), is 0.5-1.5, wherein (A) is an end region of the cup portion which is located axially opposite a portion of the yoke where no pin boss portion is present, (B) is an end region of the cup portion which is located axially opposite a pin boss portion, and the sections are mirror-polished, etched with acid, and then observed through a microscope at about 100 magnifications. Therefore, the yoke has a cup portion that is uniform in crystal grain length as observed along the circumference thereof. In the case of a yoke obtained by a conventional forging process, a crystal grain length as measured at (D) is small as compared with a crystal grain length as measured at (C), wherein (C) is an end region of a cup portion which is located axially opposite a portion of the yoke where no pin boss portion is present, and (D) is an end region of the cup portion which is located axially opposite a pin boss portion. Specifically, the ratio of a crystal grain length as measured at (C) to a crystal grain length as measured at (D); i.e., (C)/(D), is not greater than 0.5, indicating that the cup portion is not uniform in crystal grain length.

[0077]

The manufacturing method of the present invention implements sing-stage closed forging that replaces multi-stage forging employed in a conventional manufacturing method, thereby eliminating the need to use dies dedicated to individual stages.

[0078]

According to the manufacturing method of the present invention, forming is performed while the upper and lower dies are in a closed condition. Thus, no flash is formed on the exterior surface of an as-forged article, thereby eliminating the need to perform trimming. Therefore, the manufacturing method of the present invention can manufacture a yoke that does not bear a trimming mark. Also, the manufacturing method of the present invention enhances yield in terms of material utilization. As a result, a manufactured yoke is characterized in that an outer circumferential surface thereof does not bear a trimming mark, and is thus favorable in terms of strength and appearance.

[0079]

[Examples]

Yoke preforms shown in FIG. 6 were manufactured by use of the apparatus shown in FIG. 2.

The upper die of the employed die had the ring knock incorporated therein for forming a cylindrical cup shape. In manufacture of yoke preforms of Examples and Comparative Examples, back pressure generation means and the back pressure imposed on the ring knock were changed as shown in

Tables 1 and 2. In manufacture of the yoke preforms appearing in Table 1, the gas cushion was used. The results of manufacture are shown in Tables 1 and 2. The filling rate for evaluation sake was obtained in the following manner: the bottom dead center was raised to the position of starting material flow to the cup-forming cavity, so as to obtain an article in process of forming, and the volume of a pin boss portion of the obtained article was divided by the volume of the pin-boss-forming cavity of the die to thereby obtain a pin-boss-forming cavity filling rate. The cup end waviness (difference in height or height variation) of the cup portion was defined as the difference between the highest position and the lowest position along the circumference of the cup portion.

[0080]

A continuously cast bar of aluminum alloy A6061 having a diameter of 75 mm was sewn into pieces each having a length of 85 mm by use of a circular saw machine. The cut material pieces were heated to 450°C and then upset by use of the upsetting die having a diameter of 115 mm, thereby obtaining forging workpieces each having a diameter of 114.3 mm and a thickness of 40 mm. A graphite lubricant was applied to the obtained forging workpieces, which were then preheated to 450°C. Each of the thus-preheated workpieces was placed in the lower die. The upper die was caused to lower to start forming through loading in the axial direction. The upper die drops while being fitted into the bore of the lower die,

thereby forming the pin boss portion. Subsequently, as the forming load increases, the ring knock rises, thereby forming the cup portion. After completion of forming, an as-forged article was ejected from the die by means of the knockout mechanism.

[0081]

Forging conditions: press speed 25 spm (strokes/minute); and back pressure generated by back pressure generation mechanism 0-26 kg/mm^2 as shown in Tables 1 and 2.

[0082]

The forged articles; i.e., the yoke preforms, of the Examples exhibited little cut end waviness. Since the die structure does not allow formation of a flash at a die-parting portion of each yoke preform, yoke preforms bearing no trimming mark could be obtained without employment of a trimming process. The concentricity between the inner and outer cylindrical walls of the cup portion was 0.11 mm. Test pieces were cut out from the end regions of the cup portions of the yoke preforms of the Examples. The test pieces were mirror-polished and then etched with acid, followed by observation through the microscope at about 100 magnifications. The observation revealed that the ratio of a crystal grain length as measured at (B) to a crystal grain length as measured at (A); i.e., (B)/(A), was 0.5-1.5, wherein (A) is an end region of the cup portion which is located axially opposite a portion of the yoke preform where

no pin boss portion is present, and (B) is an end region of the cup portion which is located axially opposite the pin boss portion.

[0083]

Test pieces were cut out from the pin boss portions of the yoke preforms of the Examples. The tension loading test on the test pieces revealed that the tensile strength was 400 MPa, and the Young's modulus was 75 kN/mm^2.

[0084]

[Table 1]

	Back pressure $[kg/mm^2]$	Filling rate	Height variation of cup portion of forged article	Buckling of cup portion
Example 1	0.5	75%	8 mm	Absent
Example 2	1	85%	6 mm	Absent
Example 3	5	95%	4 mm	Absent
Example 4	25	100%	0 mm	Absent
Comparative Example 1	0	50%	25 mm	Absent
Comparative Example 2	0.4	70%	10 mm	Absent
Comparative Example 3	26	100%	0 mm	Present

The filling rate associated with the pin-boss-forming cavity was measured at a point in time at which the material begins to flow into the cup forming cavity.

[0085]

[Table 2]

	Initial back pressure [kg/mm^2]	Back pressure at stroke end [kg/mm^2]	Back pressure generation unit	Height variation of cup portion of forged article
Example 5	2	0.5	Hydraulic cushion	6 mm
Example 6	5	2	Hydraulic cushion	4 mm
Example 7	0.5	0.8	Gas cushion	8 mm
Example 8	1	1.5	Gas cushion	4 mm

[0086]

[Effects of the Invention]

The manufacturing method of the present invention is characterized by comprising a forging step for forming a universal joint yoke preform from a workpiece placed in a die comprising an upper die and a lower die, which define a closed space, the forging step being performed such that, while a back pressure not lower than 0.5 kg/mm^2 is applied to an end of a prospective universal joint yoke cup portion of the workpiece via a ring knock, material of the workpiece is allowed to flow into a pin-boss-forming cavity adapted to form a pin boss portion extending opposite the prospective cup portion, until a filling rate not lower than 75% is reached, and then the ring knock is moved in the direction opposite the regular forming direction of the upper or lower die in which the ring knock is disposed, so as to initiate flow of workpiece material toward the prospective cup portion.

Thus, the manufacturing method can form a yoke having a cup portion of a uniform excess-metal height while suppressing the formation of underfill or an unfilled portion, and thus can manufacture yokes—whose preforms are small in quantity of cutting—at high productivity, which is attained by enhanced yield in terms of material utilization and reduced man-hours.

[Brief Description of the Drawings]

[Fig. 1]

Fig. 1 is a sectional view showing a yoke forging step of the present invention as viewed in the middle of a forging stroke.

[Fig. 2]

Fig. 2 is a sectional view showing the yoke forging step of the present invention as viewed when the forging stroke is at the bottom dead center.

[Fig. 3]

Fig. 3 is a sectional view showing the yoke forging step of the present invention as viewed when the forging stroke is at the top dead center.

[FIG. 4]

Fig. 4 is a sectional view showing the structure of an upper die of the present invention for use in forming a yoke.

[Fig. 5]

Fig. 5 is a sketch showing an as-forged yoke preform of the present invention.

[Fig. 6]

Fig. 6 is a sketch showing a finished yoke obtained by machining the preform.

[Fig. 7]

Fig. 7 is a sectional view showing a die configuration in which a movable ram is disposed in a lower die of the present invention.

[Fig. 8]

Fig. 8 is a schematic representation showing the configuration of a forging apparatus used in the present invention.

[Fig. 9]

Fig. 9 is a diagram showing an example of back pressure generation means used in the present invention.

[Fig. 10]

Fig. 10 is a diagram showing another example of back pressure generation means used in the present invention.

[Fig. 11]

Fig. 11 is a diagram showing the relationship between back pressure generation means used in the present invention and a height variation of a cup portion.

[Fig. 12]

Fig. 12 is a schematic representation showing a propeller shaft (i.e., drive shaft).

[Fig. 13]

Fig. 13 is a schematic sectional view showing a die configuration of a conventional forging process (top dead center).

[Fig. 14]

Fig. 14 is a schematic sectional view showing a die configuration of the conventional forging process (bottom dead center).

[Fig. 15]

Fig. 15 is a schematic representation showing a conventional two-stage forging process.

[Fig. 16]

Fig. 16 is a sketch showing an as-forged preform obtained by a conventional flash-emerging forging process and a trimmed preform.

[Fig. 17]

Fig. 17 is a schematic representation showing a forging machine equipped with a conventional back pressure apparatus, and a die set.

[Description of Reference Numerals]

1. Upper bolster
2. Upper die for use in conventional forging process
3. Stripper
4. Lower die for use in conventional forging process
5. Lower bolster
6. Forging workpiece
7. As-forged article

31. Upper die for use in preforming
32. Lower die for use in preforming
33. Knockout pin
34. Preformed article

41. Cup portion

42. Plate portion

43. Pin boss portion

44. Flash

45. Trimming mark

61. Knockout bar

62. Knock block

63. Pressure-bearing plate

64. Knockout pin

65. Lower die of the invention

66. Center punch

67. Ring knock (movable ram)

68. Pneumatic cylinder pressure transmission spindle

69. Punch holder

70. Pneumatic cylinder supporting pressure-bearing plate

71. Pneumatic cylinder

72. Pneumatic cylinder gas confinement section

73. Article in process of forming

74. Gas cushion

91. Shaft coupling portion

94a, 94b. Pin holes

103. Upper die

104. Spray nozzle

105. Lower die

107. Knockout pin

108. Spray moving unit

109. Spray rotating unit

110. Spray shaft

111. Rear end of transmission

112a, 112b, 112c. Yokes

113a, 113b, 113c. Cross members

114. Shaft

115. Center bearing

116. Mount insulator

117. Body (chassis)

118. Weld zone

119. Final drive

201. Lower die

202. Upper die

203. Center bush

204. Pressure-bearing plate

221. Forging machine

222a, 222b. Hydraulic cylinders

223. Hydraulic piping

224. Hydraulic pressure generation unit

225. Press operation monitoring unit

226. Lower die

227. Upper die

228. Guide post

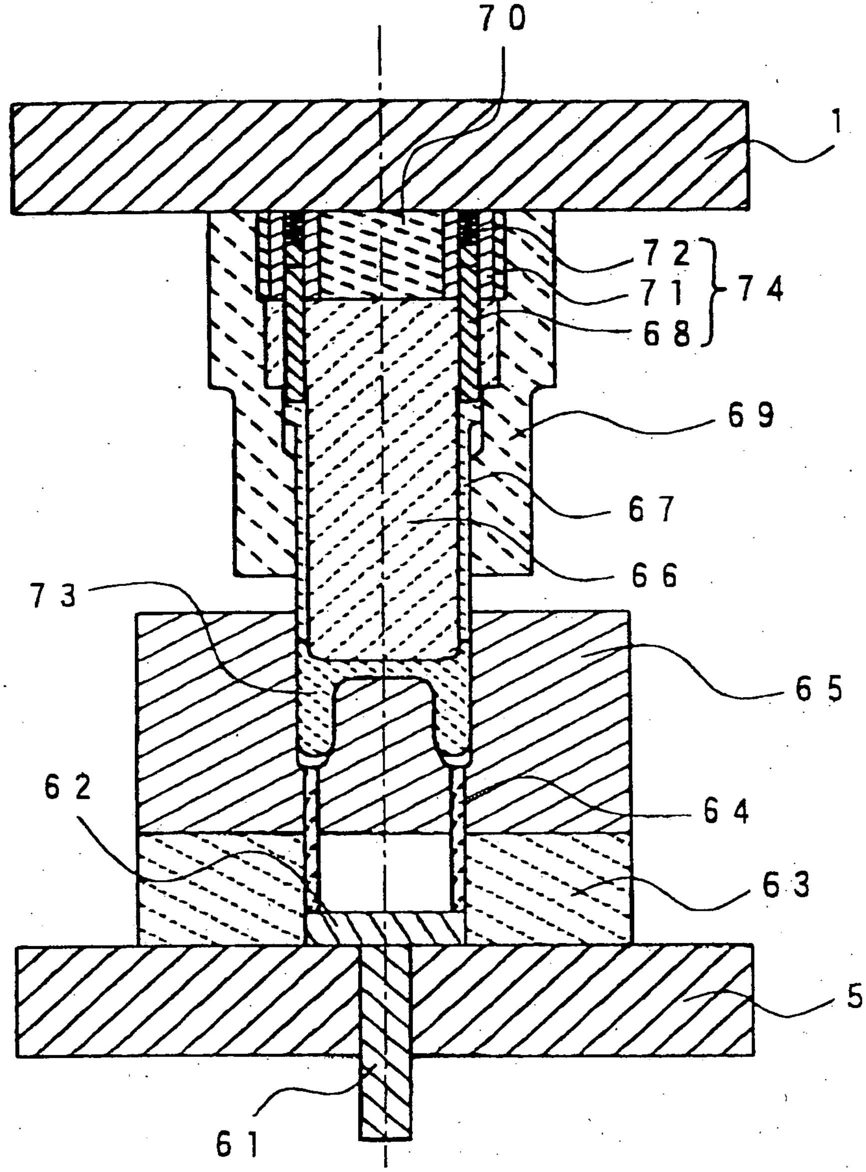
229. Upper die set plate

230. Lower die set plate

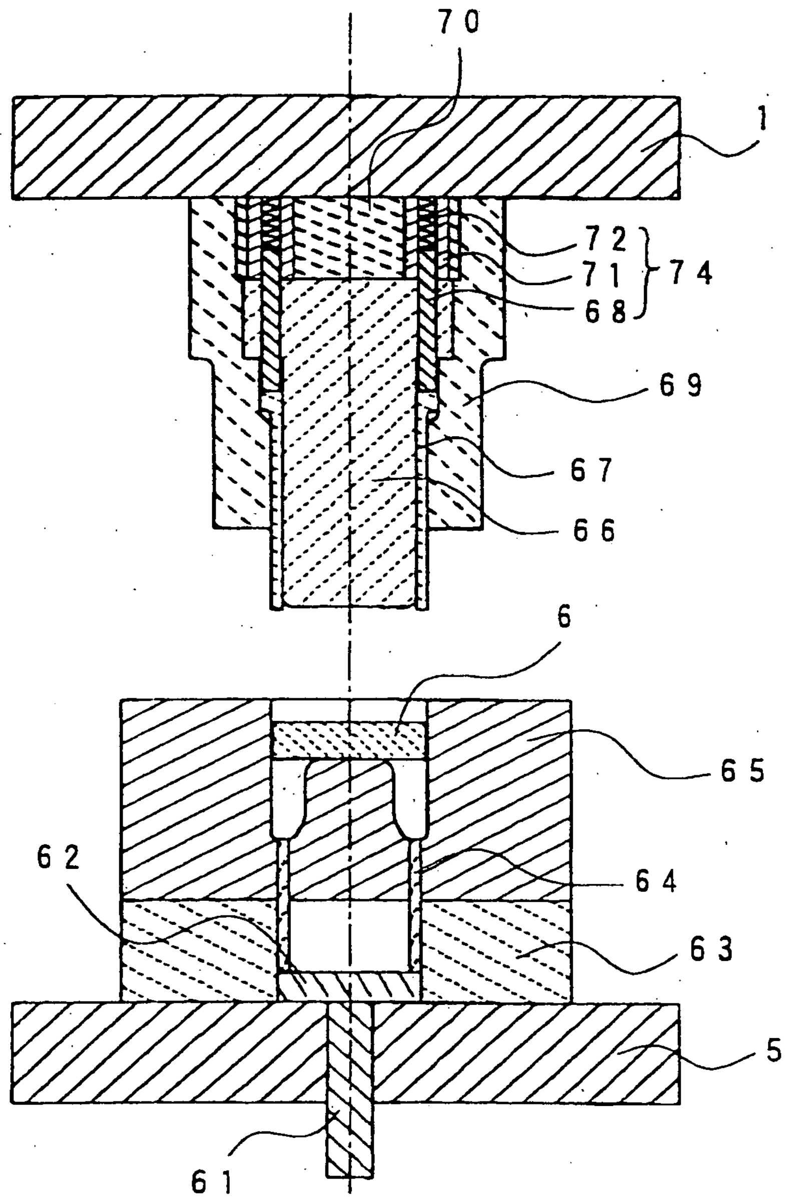
231. Pneumatic cylinder

[Document Name] Drawings

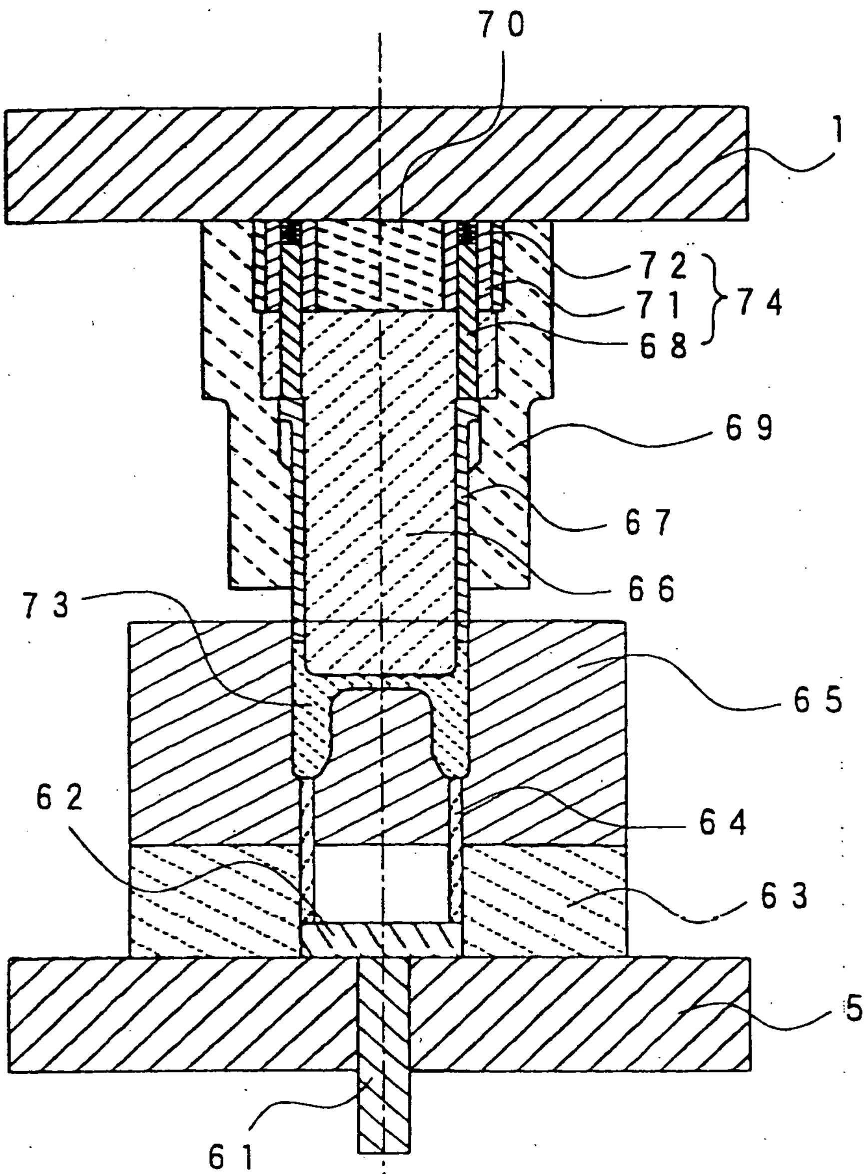
[Fig. 1]



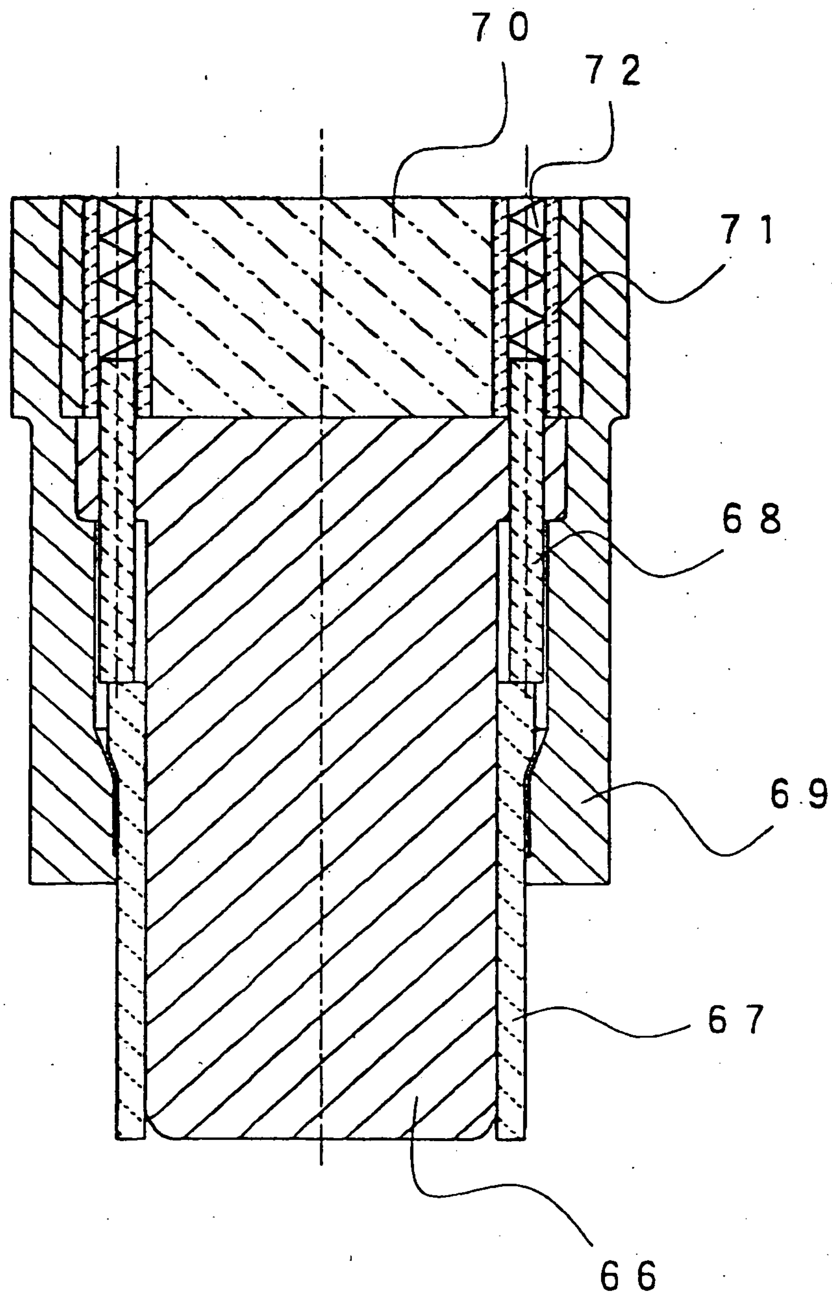
[Fig. 2]



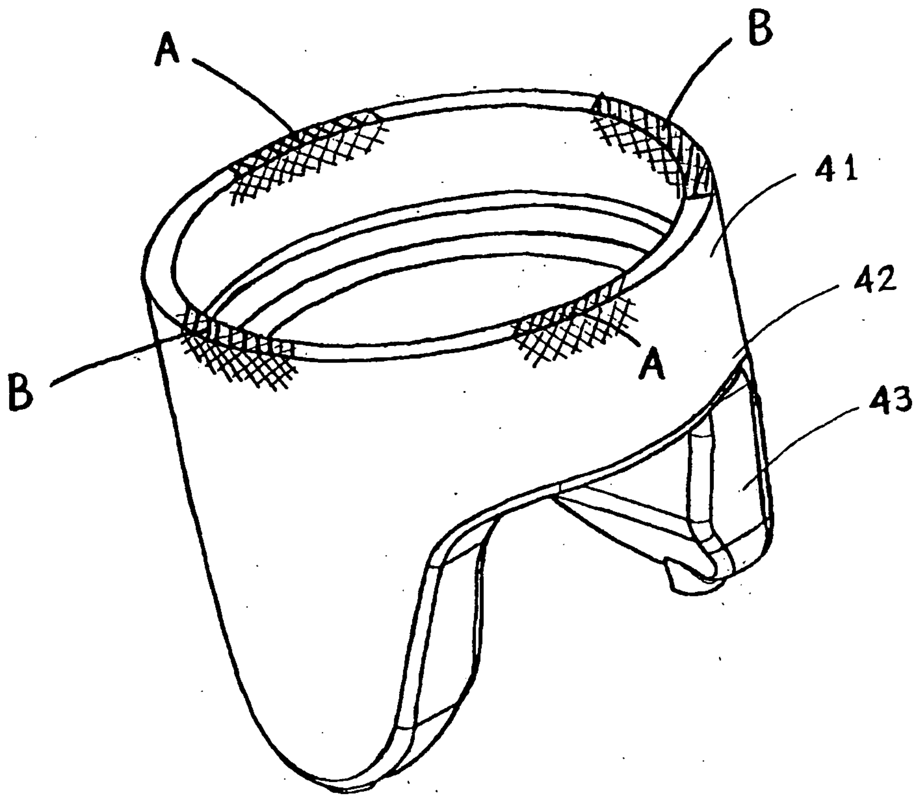
[Fig. 3]



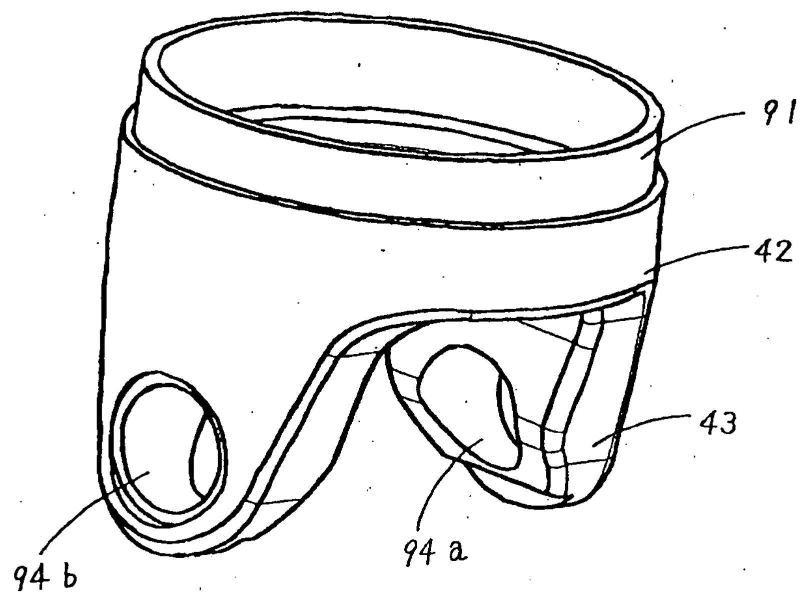
[Fig. 4]



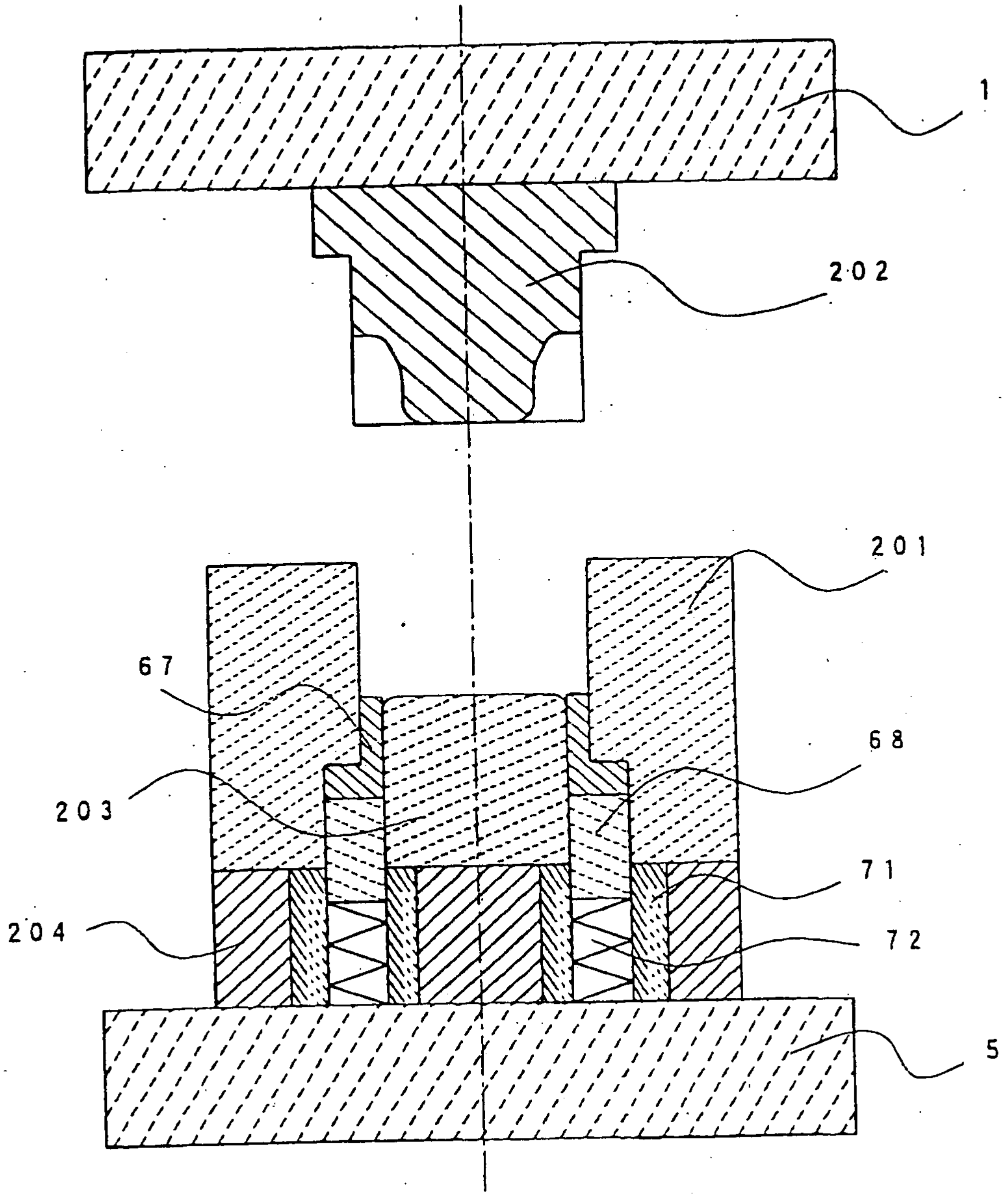
[Fig. 5]



[Fig. 6]

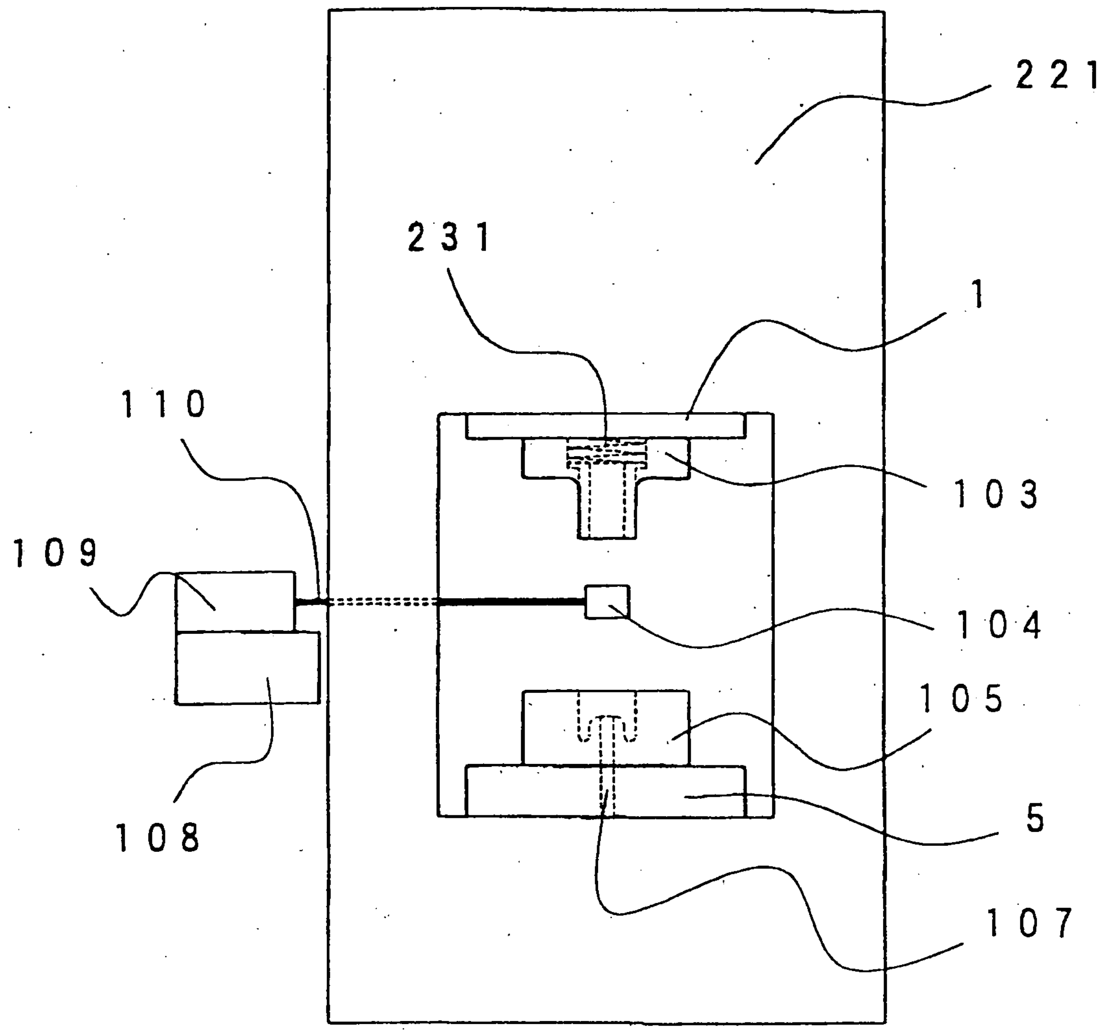


[Fig. 7]

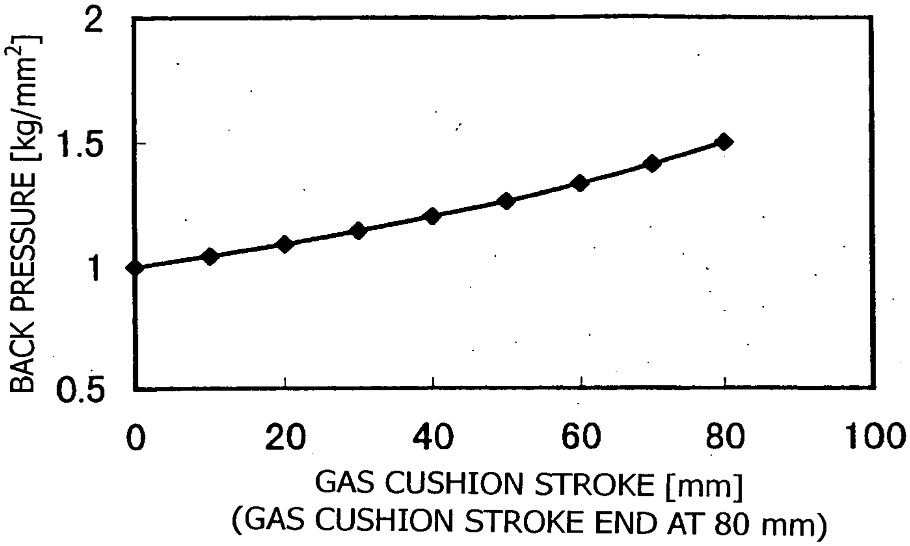


10/500105

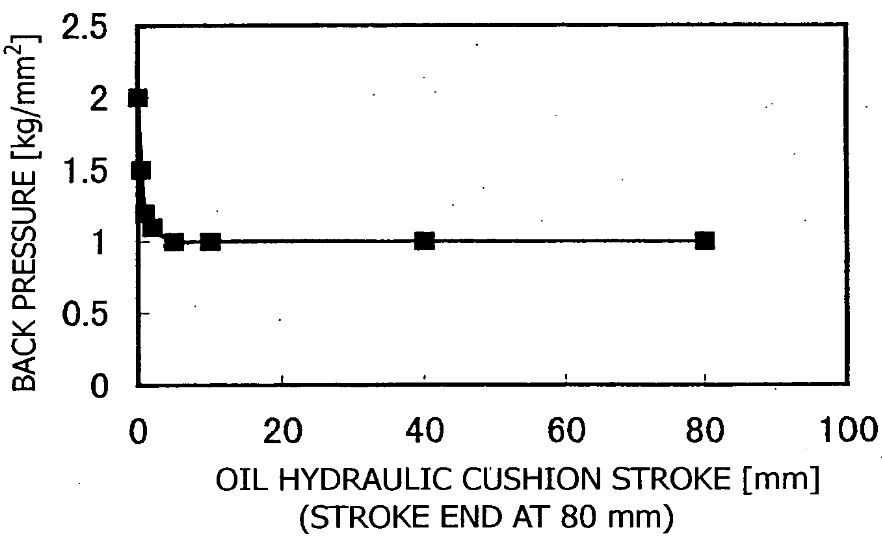
[Fig. 8]



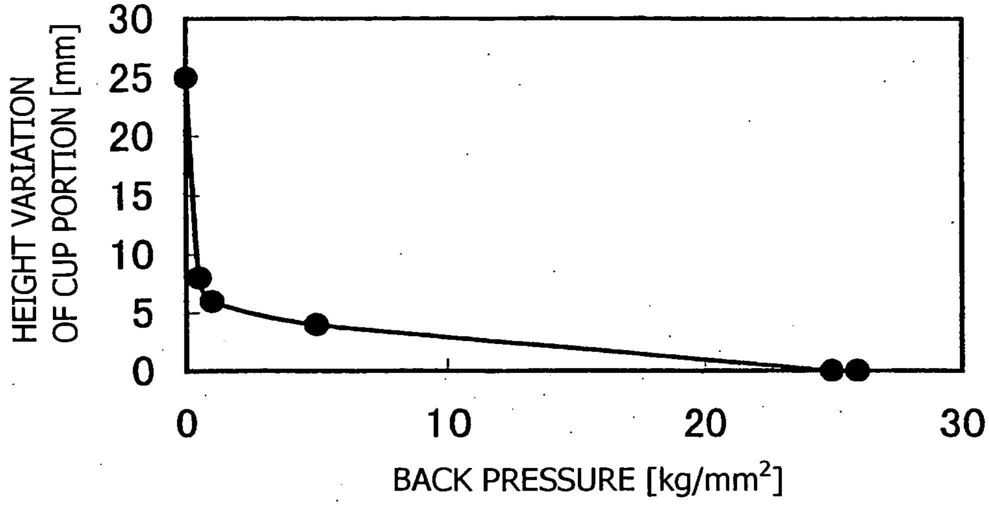
[Fig. 9]


BACK PRESSURE [kg/mm²]
2
1.5
1
0.5
0
20
40
60
80
100
GAS CUSHION STROKE [mm]
(GAS CUSHION STROKE END AT 80 mm)

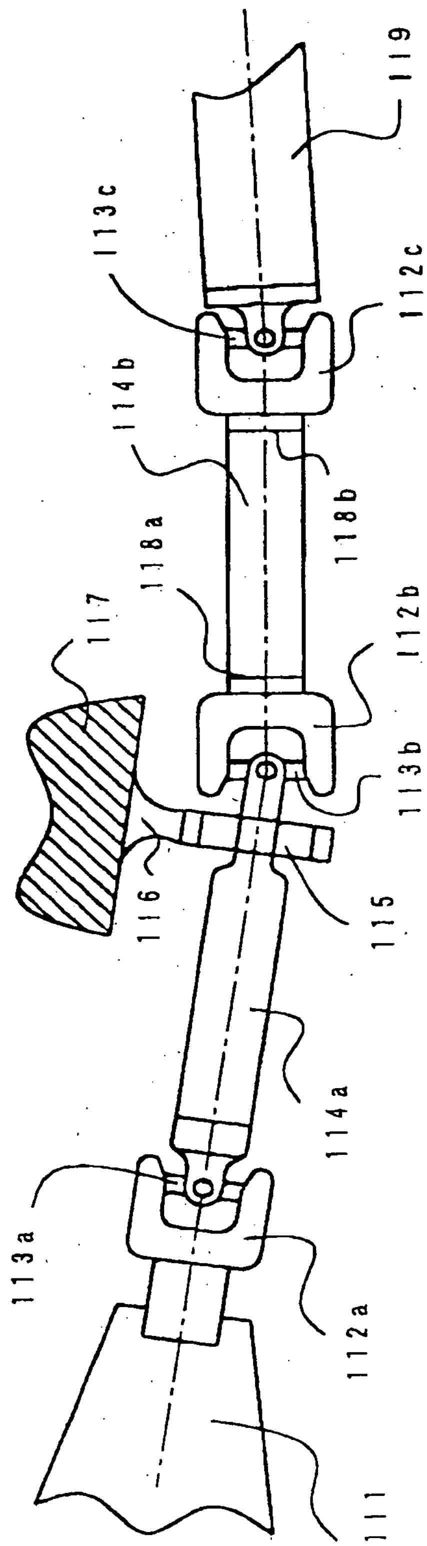
[Fig. 10]


BACK PRESSURE [kg/mm²]
2.5
2
1.5
1
0.5
0
0
20
40
60
80
100
OIL HYDRAULIC CUSHION STROKE [mm]
(STROKE END AT 80 mm)

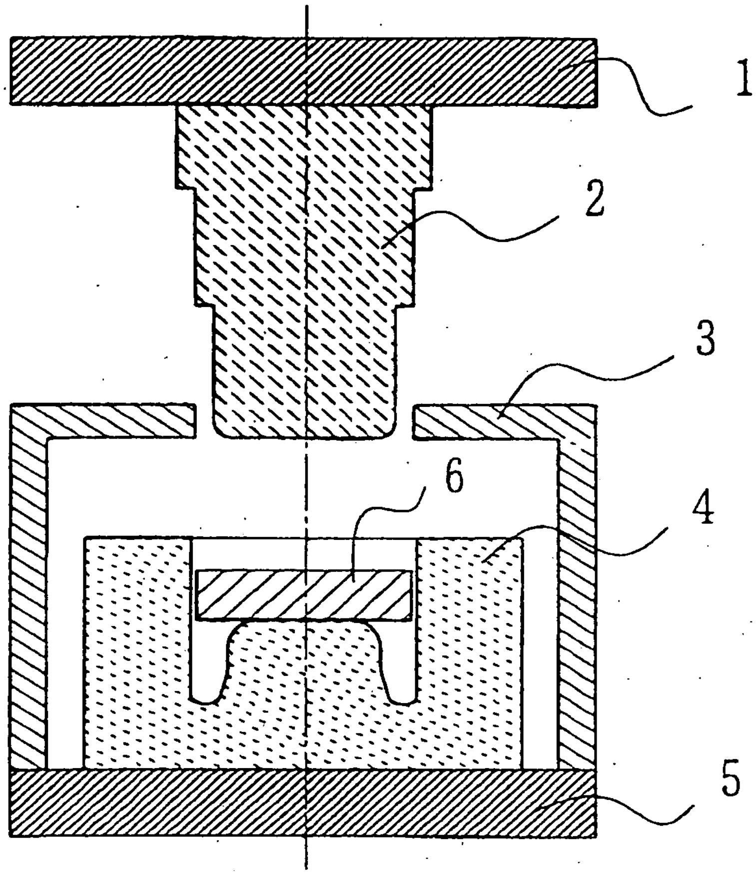
[Fig. 11]


HEIGHT VARIATION OF CUP PORTION [mm]
30
25
20
15
10
5
0
0
10
20
30
BACK PRESSURE [kg/mm2]

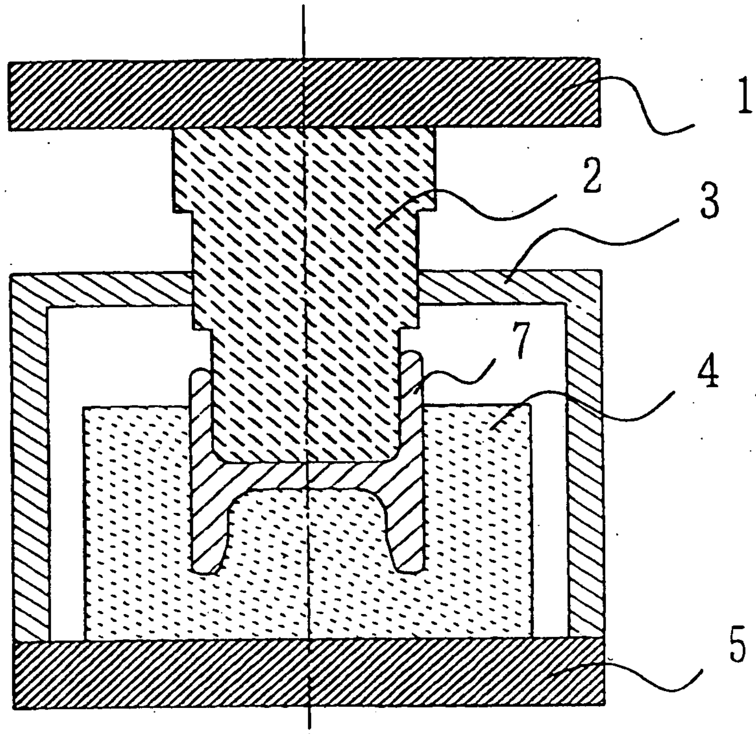
[Fig. 12]


119
113c
112c
114b
118b
118a
117
112b
113b
116
115
114a
113a
112a
111

[Fig. 13]



[Fig. 14]



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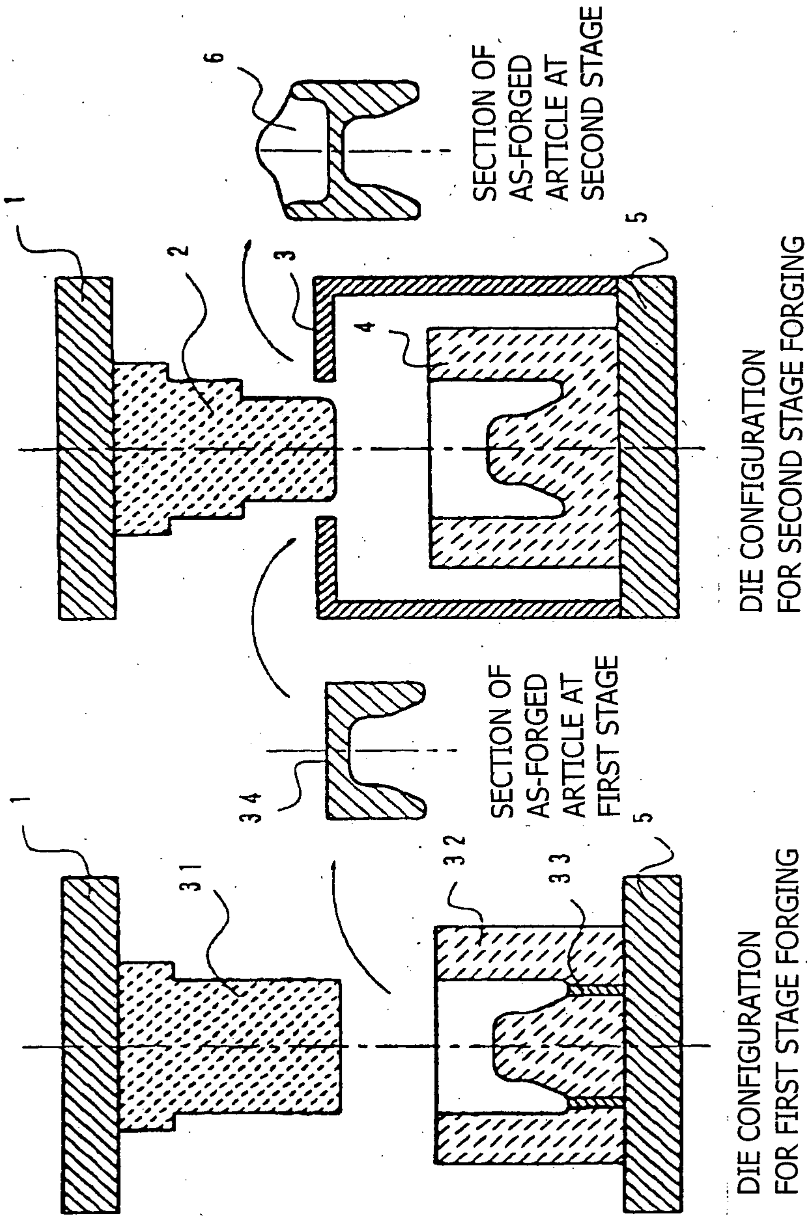
[Fig. 15]



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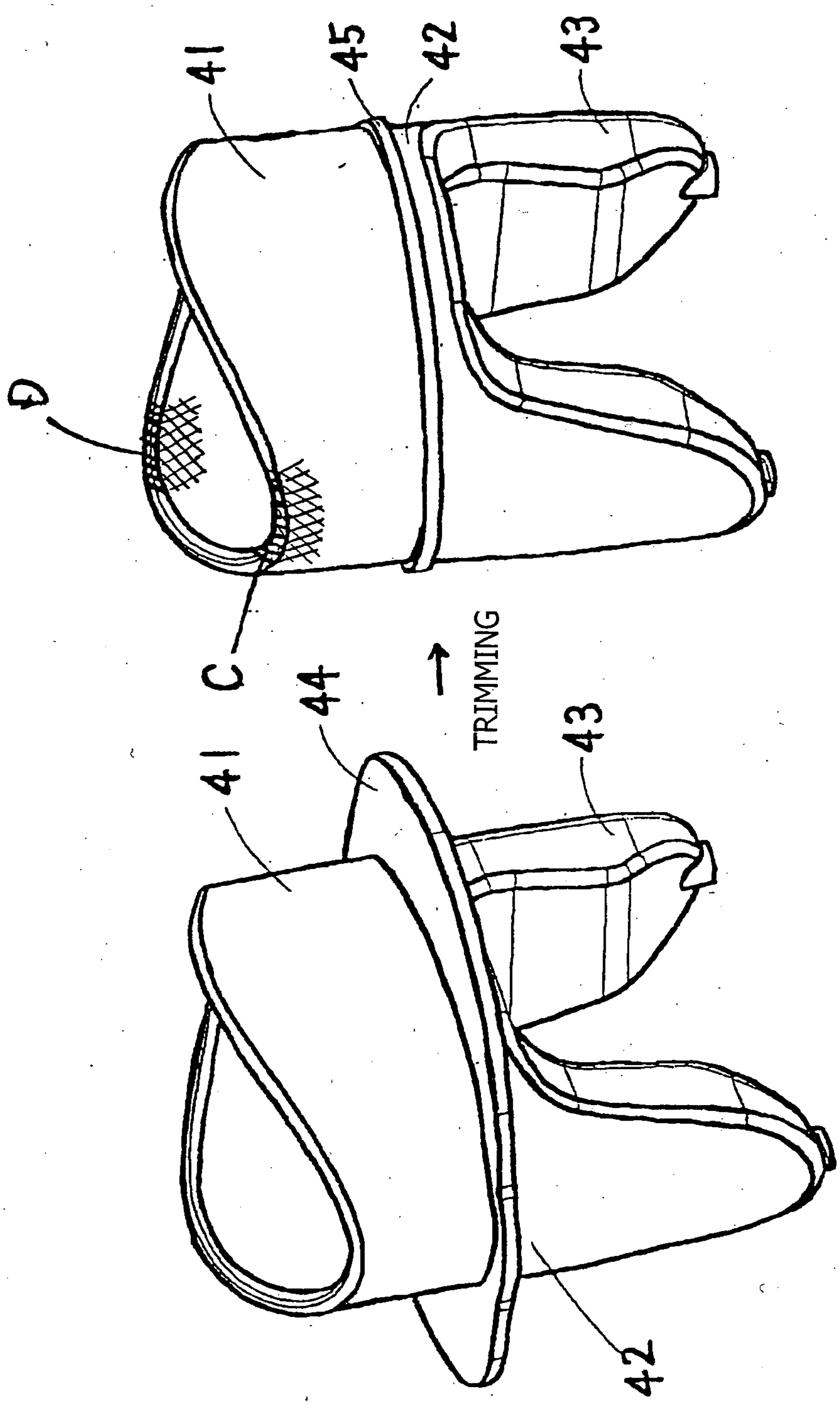
June 04
15 of 10/500105

[Fig. 16]



[Fig. 17]